

TEMPERATURE QUESTIONS

TEACHERS NOTES

If you think of

- Additional questions,
- Ways in which these answers could be improved,
- Anything else you want to tell me, then

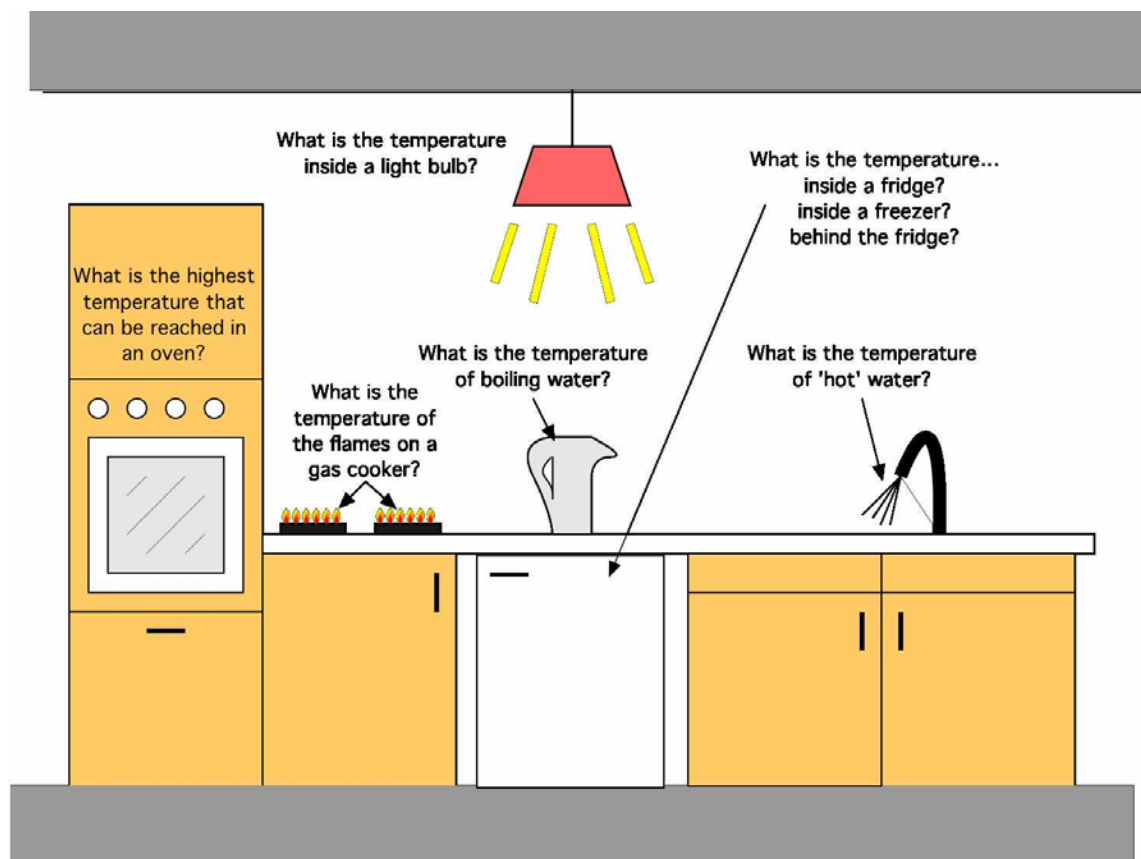
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Temperatures in the kitchen



Gas Oven

Potentially, an oven could get as hot as the gas in the flames that heat it i.e. up to 1000 °C. However, to do that the insulation around the oven would have to be very good. In normal use temperatures are limited to around 200 °C (Gas mark 8). At this temperature you will notice that the outside of the oven is quite hot. The temperature is limited by a *thermostat*. When the temperature rises above the set level, the thermostat restricts the gas flow and the oven cools to just below the set temperature, at which point the gas comes on again. This heats the oven to above its set temperature, which restricts the gas flow again. In this way the temperature cycles around the desired set point.

Electric Oven

In an electric oven, electricity is passed through wires which get hot, up to 700 °C or so, and which then heat the oven. The temperature is restricted to around 200 °C by a thermostat.

Gas Cooker

The gas in the flames on the hob of a gas cooker vary greatly in temperature but at their hottest part are probably around 1000 °C. The different colours in the flames reflect the different temperatures and types of molecules in the different parts of the flame. All the light you see comes from oscillations of electrons in the outer parts of

the molecules. If the electrons oscillate around 1000 million million times per second then we see blue light. If the electrons oscillate at 'only' 400 million million times per second then we see red light. The yellow colour often seen in flames arises from microscopic pieces of solid carbon which are heated in the flame. In general this indicates that the flames are not burning efficiently and that there is a little bit too much fuel being used for the amount of oxygen in the flame.

Kettle

The water in a kettle boils at close to 100 °C. More precisely, the actual boiling temperature depends on the pressure of the gas above the liquid which depends on (a) the weather (b) the design of the kettle and (c) the depth of the liquid. Also, there is a big flow of heat through the water which tends to raise its temperature slightly above the standard value of 99.975 °C. (Water boiled at 1 atmosphere pressure at 100 degrees *centigrade* by definition. The *celsius* scale differs slightly and the boiling temperature of water at 1 atmosphere pressure is actually around 99.975 celsius.)

Fridge

The temperature at the bottom of fridge should be around 5 celsius. The temperature in the freezer compartment should be below -18 celsius. The (outside) back of the fridge will be considerably warmer: typically 35 °C.

Fridges operate by 'pumping' heat. Remember heat only flows spontaneously in one direction: from hotter to colder. So how does a fridge make heat flow out of the colder part (the fridge) to a hotter part (the back)? It utilises a refrigerant, a liquid which is pumped through tubes which run from the inside to the outside of the fridge.

- The refrigerant liquid is expanded through a nozzle and cools so that it is colder than the inside of the fridge (think of butane [lighter fluid] flowing from a gas cylinder). Heat flows from the fridge into the liquid.
- The liquid is pumped from the inside of the fridge to the back and is then compressed so that it gets hot. Heat the flows out of the refrigerant into the room.
- The liquid is expanded again and sent back to the inside of the fridge. And round and round.

Water

Our human judgement of water temperature is very subjective and not very accurate. Water feels hot when it is at or above our body temperature (≈ 37 celsius). But how it feels depends on how hot our skin is. So if our skin is cold, even water at 28 °C can feel very warm.

Light bulb

The outside of a light bulb can easily reach 100 °C. So be careful. But the filament inside a normal light bulb can easily reach 2000 °C! At this temperature almost everything (aside from tungsten and a few other materials) melts. The best way to measure temperatures of this magnitude is by looking at the amount of light of a given colour which is emitted. Hot objects appear 'red-hot' then yellow and then 'white hot' as they are progressively heated. This colour change can be quantified to permit accurate thermometry of hot objects.

Temperatures in space

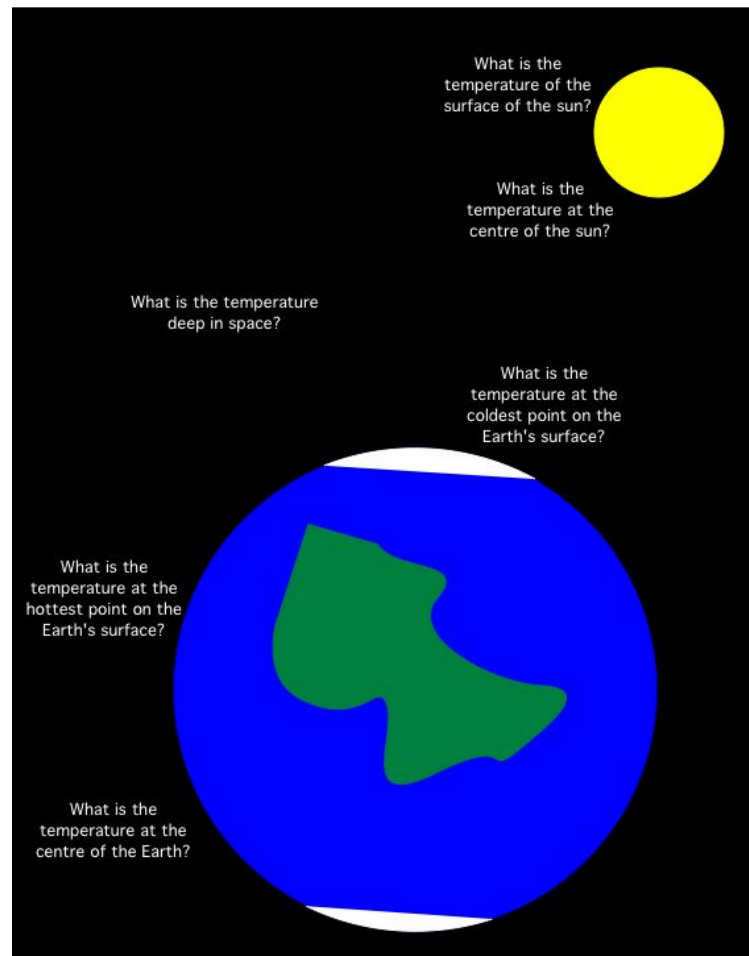
Surface of the Sun

The temperature of the surface of the Sun can be determined by looking at the colour and intensity of light leaving the surface. It is around 6400 °C

Centre of the Sun

The temperature of the centre of the Sun is inferred by examining the massive flux of neutrinos that the Sun emits. These weakly interacting particles travel outward from the centre of the sun without interacting with other particles at all! Most of the neutrinos also pass through the Earth unaffected which makes detecting them at all quite a challenge.

Based on these experiments, the centre of the Sun is estimated to be at around 10 million °C.



Deep space

The temperature of deep space far from stars or planets is around $-270\text{ }^{\circ}\text{C}$ or just over 3 degrees above absolute zero. This can be measured by detecting the microwaves (high frequency radio waves) emitted by objects at this temperature.

Centre of the Earth

Despite being only 6400 km away (rather than 150 million km away) the temperature at the centre of the Earth is much harder to measure or infer than the temperature of the Sun. We know it is hot: the temperature rises by $\approx 30\text{ }^{\circ}\text{C}$ for every kilometre below the Earth's surface. This is a very rapid change. That is $1\text{ }^{\circ}\text{C}$ for $\approx 30\text{ m}$ below the Earth's surface. Also we see hot magma emerge from volcanos that must come from somewhere hot! Our best estimates are that the Centre of the Earth is between $5000\text{ }^{\circ}\text{C}$ and $6000\text{ }^{\circ}\text{C}$, only a little colder than the surface of the Sun! If we could see it, the centre of the Earth would glow white hot.

Coldest place on Earth

The winner of the 'Coldest naturally occurring place *on the Earth's Surface*' competition is *Antarctica* where the lowest recorded winter temperature is $-80.6\text{ }^{\circ}\text{C}$. It is interesting to compare this with a record low of 'only' $-48.9\text{ }^{\circ}\text{C}$ in the Arctic. The difference arises for several reasons. Firstly, Antarctica is relatively high, with the South Pole being more than 2 km above sea level. Using a rule of thumb which applies for all climates, temperatures typically fall by between $6\text{ }^{\circ}\text{C}$ and $10\text{ }^{\circ}\text{C}$ with every km of rise above sea level. Additionally the climate in the Arctic is ameliorated by the contact with the sea (remember there is no land at the north pole so the ice is floating on the sea).

The coldest places on Earth (and indeed the entire universe as far as we know!) are inside the laboratories of a small number of physicists investigating low-temperature phenomena. It is possible to cool small objects ($\approx 1\text{ cm}^3$) to around one milli-kelvin i.e. one thousandth of a degree above absolute zero, 0.001 K or $-273.149\text{ }^{\circ}\text{C}$. In the UK there are fridges such as these at the *NPL* in Teddington, *Royal Holloway College* in Ascot, and at the *University of Lancaster*. It is possible to cool smaller objects (consisting of just a few thousand molecules) to temperatures around a few nano-kelvin i.e. one billionth of a degree above absolute zero, 0.00000001 K or $-273.149999999\text{ }^{\circ}\text{C}$.

Hottest place on Earth

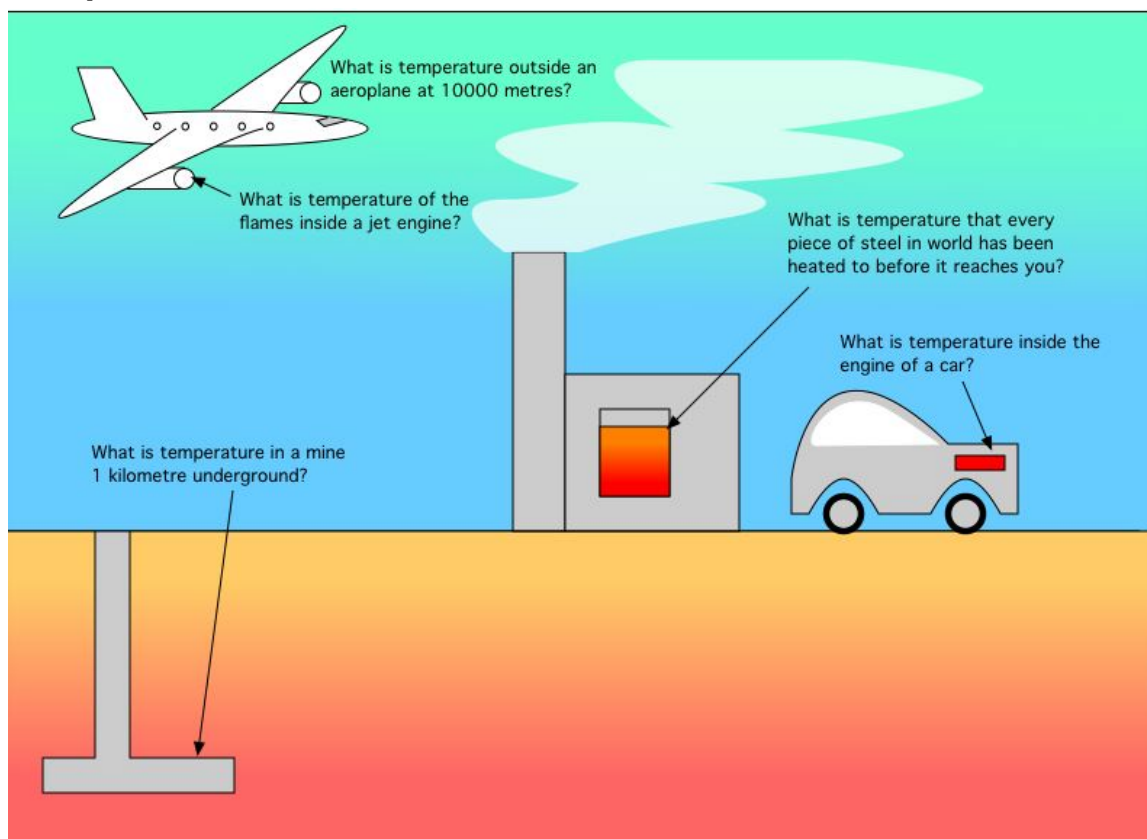
The winner of the 'Hottest naturally occurring place *on the Earth's Surface*' competition is not quite so clear cut as the competition for the coldest place on the Earth's surface. Several places in the Sahara have reported temperatures of above $50\text{ }^{\circ}\text{C}$. Determining the hottest temperature is quite hard because if the Sun actually shines directly on the thermometer then it can easily heat it above the air temperature.

An internet search tells me that El Azizia in Algeria has a reported temperature of $57.8\text{ }^{\circ}\text{C}$ while the *Dallol Depression* in Ethiopia is a desert with some areas that are more than 100 meters below sea level has reported as high as $63\text{ }^{\circ}\text{C}$. In *Death Valley* in the United States of America (another depression around 100 m below sea level) temperatures of $49\text{ }^{\circ}\text{C}$ have been reported. So whose the winner? I don't know, but the winning temperature is probably around $60\text{ }^{\circ}\text{C}$.

The hottest place on Earth would again be in a laboratory where scientists attempting to recreate conditions at the centre of the Sun can (briefly) create temperatures approaching 10 million $^{\circ}\text{C}$.

The winner of the 'Hottest naturally occurring place on the Earth'' competition would definitely be the Centre of the Earth (see above).

Temperatures on Earth



What is the temperature outside an aeroplane at 10000 m?

The temperature of the air falls at between 6 °C and 10 °C for every kilometre we rise above the ground. So at 10 km, the routine cruising height of most airliners, the temperature is somewhere between 60 °C to 100 °C colder than it is on the ground, or typically – 40 °C to –80 °C. The precise value depends on the amount of moisture in the air.

What is the temperature of the flames inside a jet engine?

The flames in the hottest part of a jet engine can reach 2000 °C. At this temperature, the molecules in the hot gas are travelling at typically 1400 metres per second (around 3000 miles per hour). This represents an absolute maximum speed limit on the engine. This is because the plane can't be pushed faster one way than the molecules are leaving in the other direction (otherwise they wouldn't leave!) In fact other factors limit the maximum speed to well below this speed. However, it is still true in general that the hotter the flames the faster and more efficient is the engine. Unfortunately it is also has a shorter life.

What is the temperature inside a motor car engine?

Inside the cylinders of a motor car engine, hundreds of explosions every second push pistons up and down. The up and down motion of the pistons is converted to a rotary motion by a so-called *crankshaft*, and the rotation of the crankshaft drives the car. The explosions inside the cylinders are ignited by a spark and cause the temperature of the gas inside the cylinders to rise (briefly) to over 1000 °C. This increases the pressure of the gas and pushes the piston.

As with jet engines, allowing the explosions to reach higher temperatures improves the performance of the car, but shortens its life and increases the amount of pollution it emits.

What is the temperature that every piece of steel has been heated to?

To make steel, iron must be heated to around 1600 °C in order to melt it and keep it molten long enough to pour it into a mould. This applies to absolutely every piece of steel in the world. From the buckle on your watch, to the metal in your saucepan, to the door of your car. They have all been through hell to reach you!

So called 'cast iron' need only be heated to around 1350 °C in order to be made into all kinds of every day objects.

What is the temperature in a mine one kilometre underground

The temperature beneath our feet rises at around 30 °C for every kilometre we descend underground. This is an amazingly fast rate of temperature rise. The rate is not kept up as one goes deeper, but the temperature at the centre of the Earth is somewhere between 5000 °C and 6000 °C.